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Chevallet

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(54) **DEVICE FOR MEASURING NEGATIVE PRESSURES IN AN EXTRACORPOREAL BLOOD CIRCUIT**

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(52) **U.S. Cl.** **210/90**; 210/97; 73/715; 73/716; 73/717; 73/723

(58) **Field of Search** 210/86, 90, 97; 73/715, 716, 717, 723, 1.57, 1.68, 49.1

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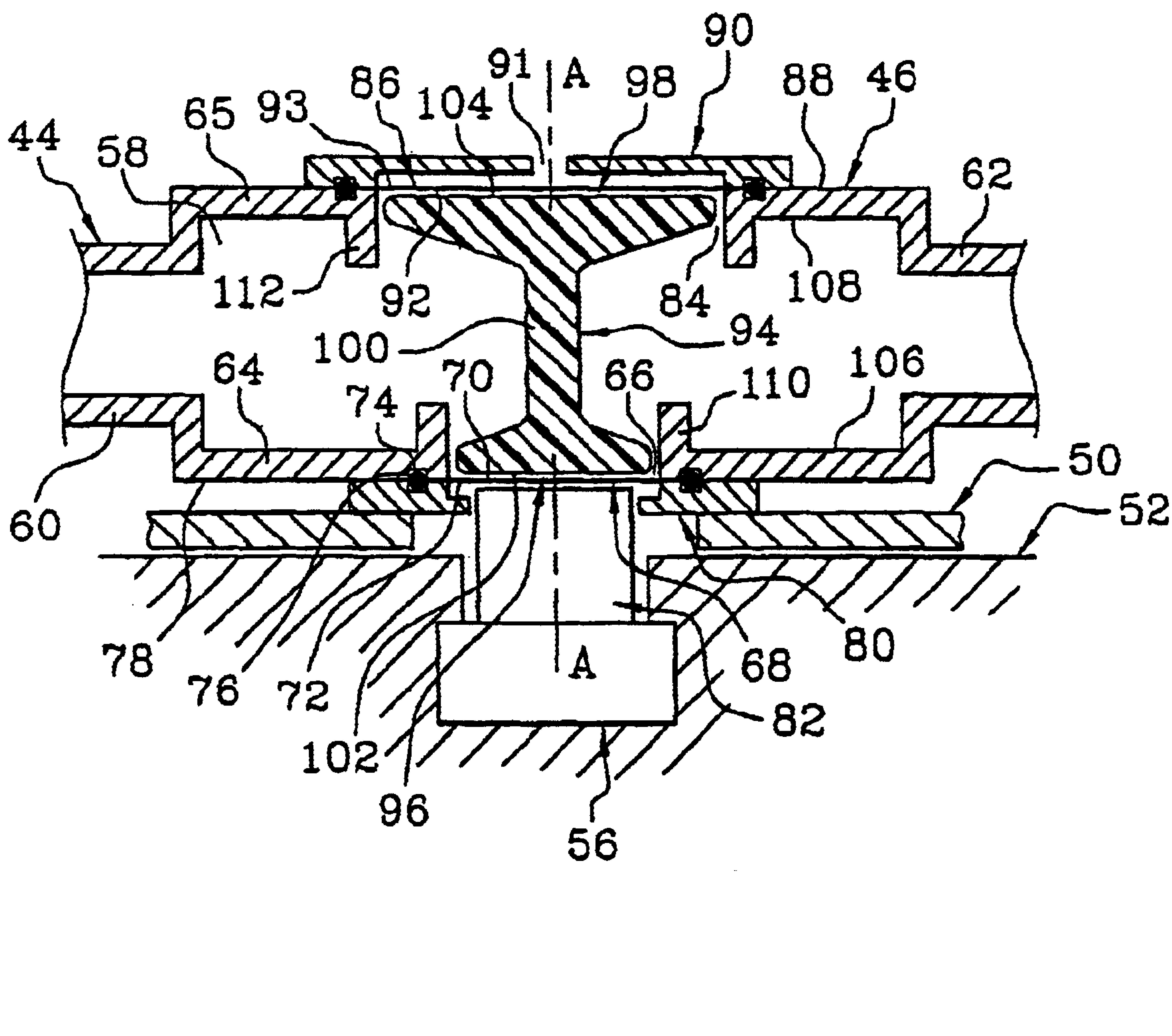
(57) **ABSTRACT**

A device for measuring the pressure of blood in a pipe **(44)** of an extracoporeal blood cicuit, includes a pressure measurement section **(46)** having a compartment **(58)** which is delimited especially by a main wall **(64)** and by a secondary wall **(65)** facing it. The two walls **(64, 65)** have a hole **(66, 84)** which is closed by a closure element **(68, 86)** which can be elastically deformed under the effect of the blood pressure, and the compartment **(58)** has a spacer **(94)** which transmits the movements from the closure element **(86)** of the secondary wall **(65)** to the closure element **(68)** of the main wall **(64)**, so that a load sensor **(56)** can measure a force which corresponds to a so-called "negative" blood pressure.

13 Claims, 3 Drawing Sheets



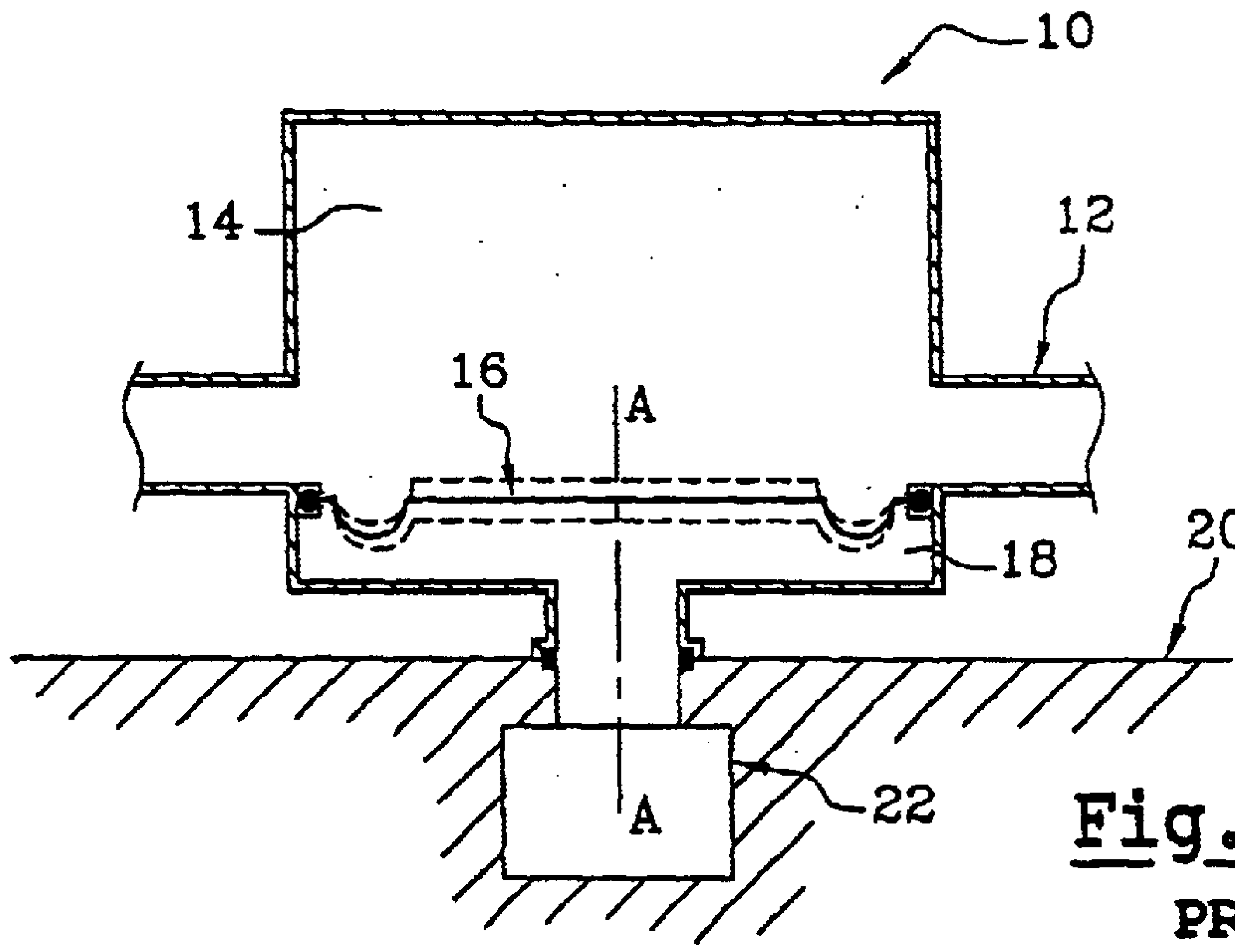


Fig. 1
PRIOR ART

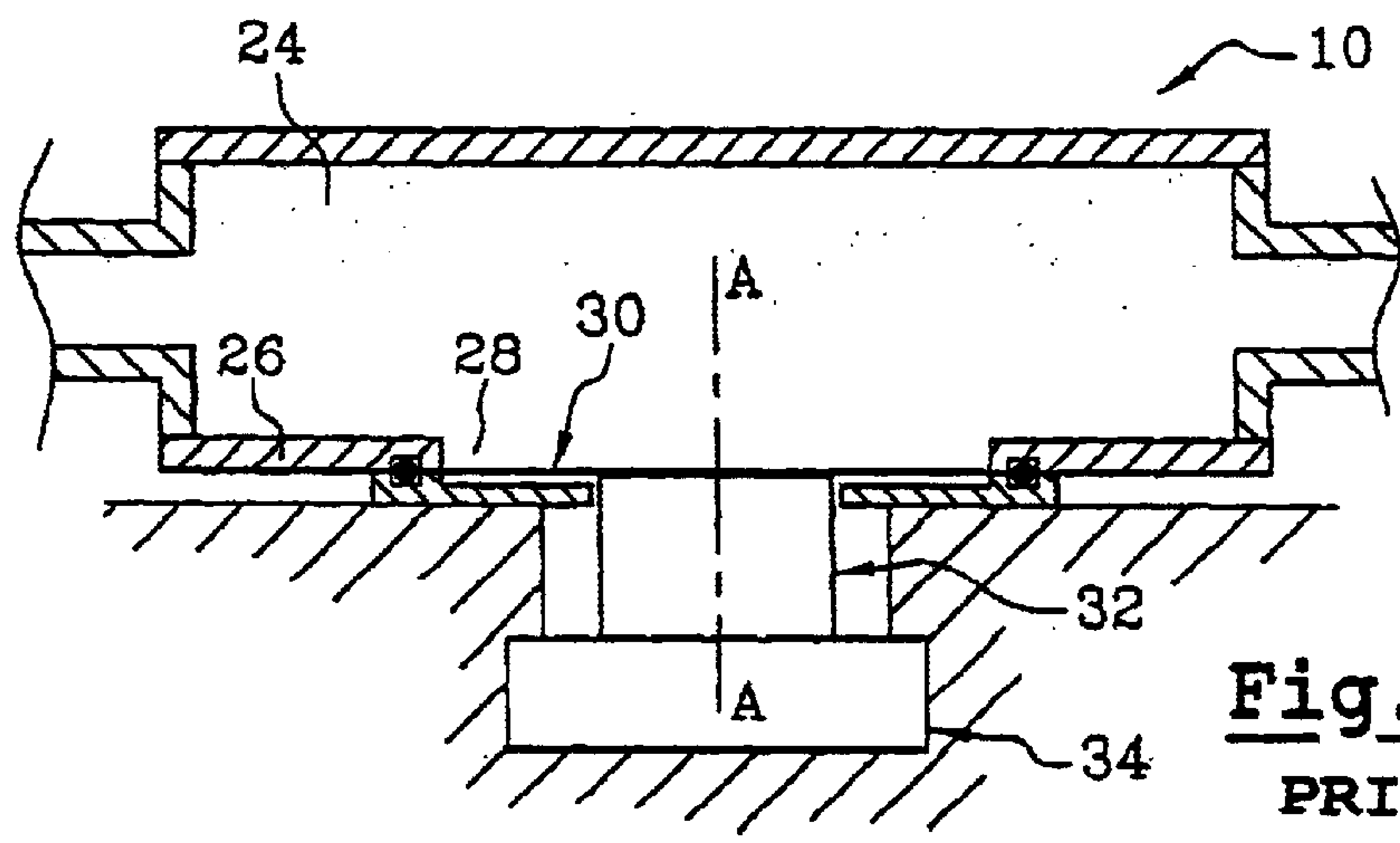


Fig. 2
PRIOR ART

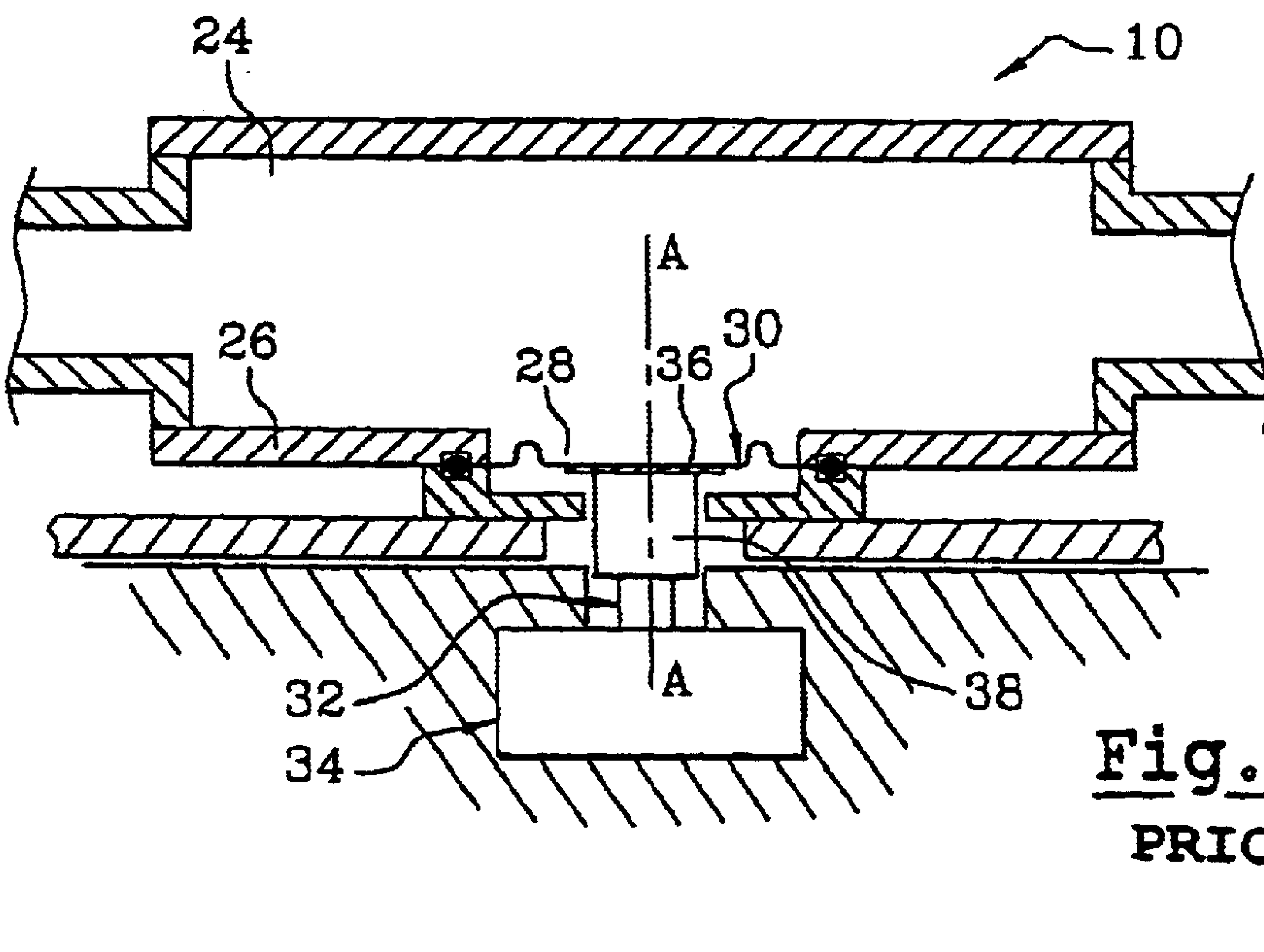


Fig. 3
PRIOR ART

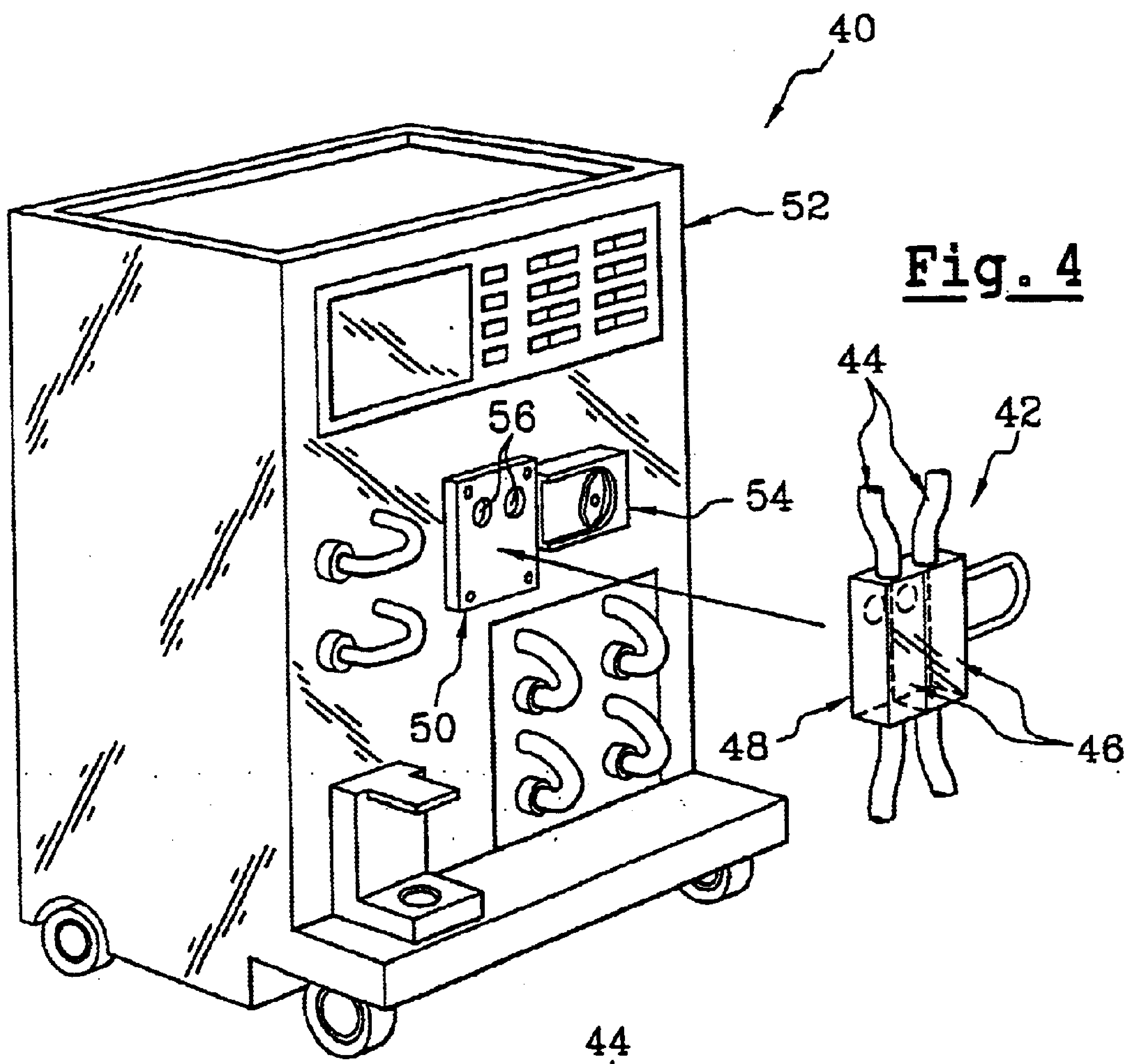


Fig. 4

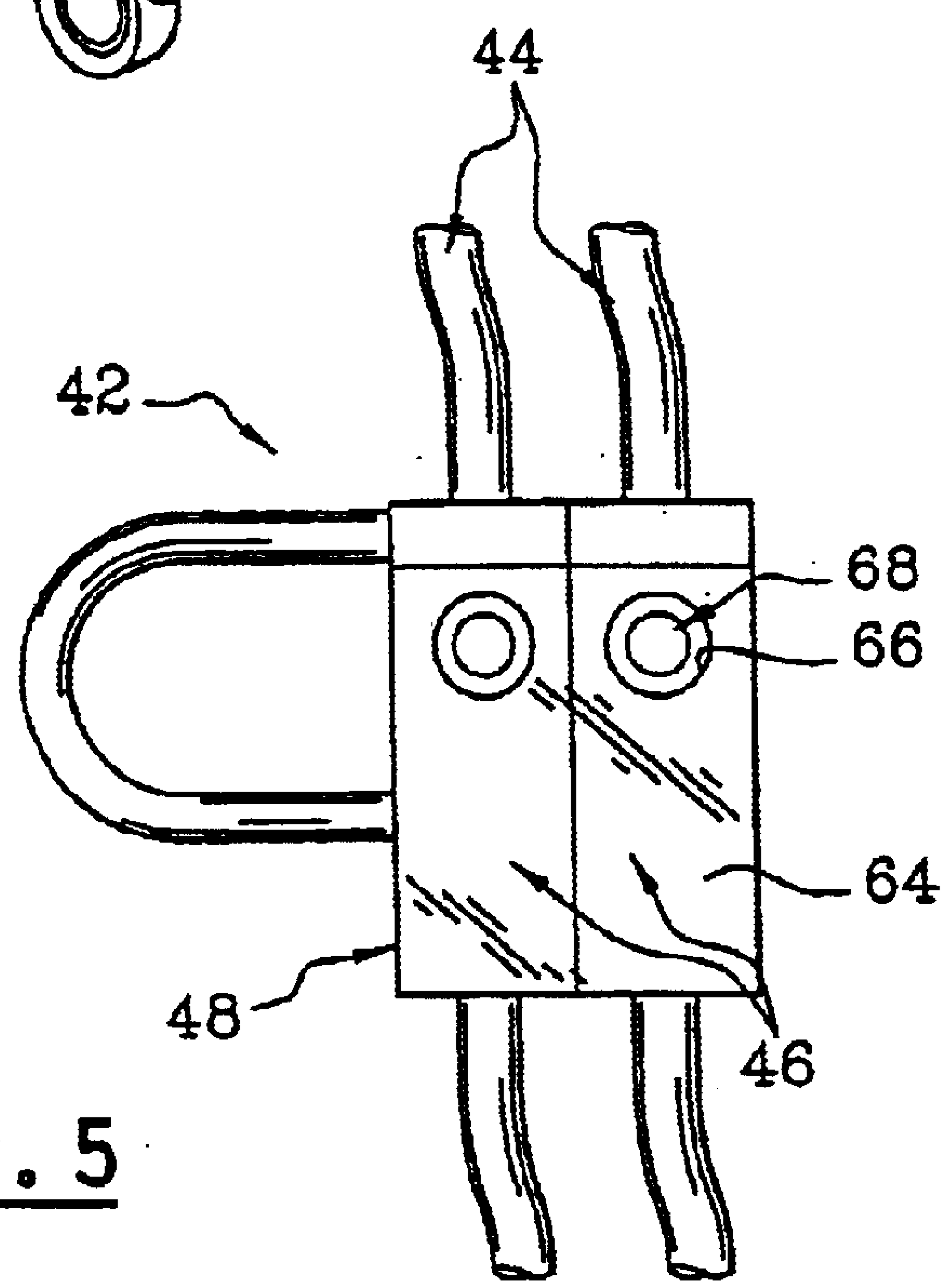


Fig. 5

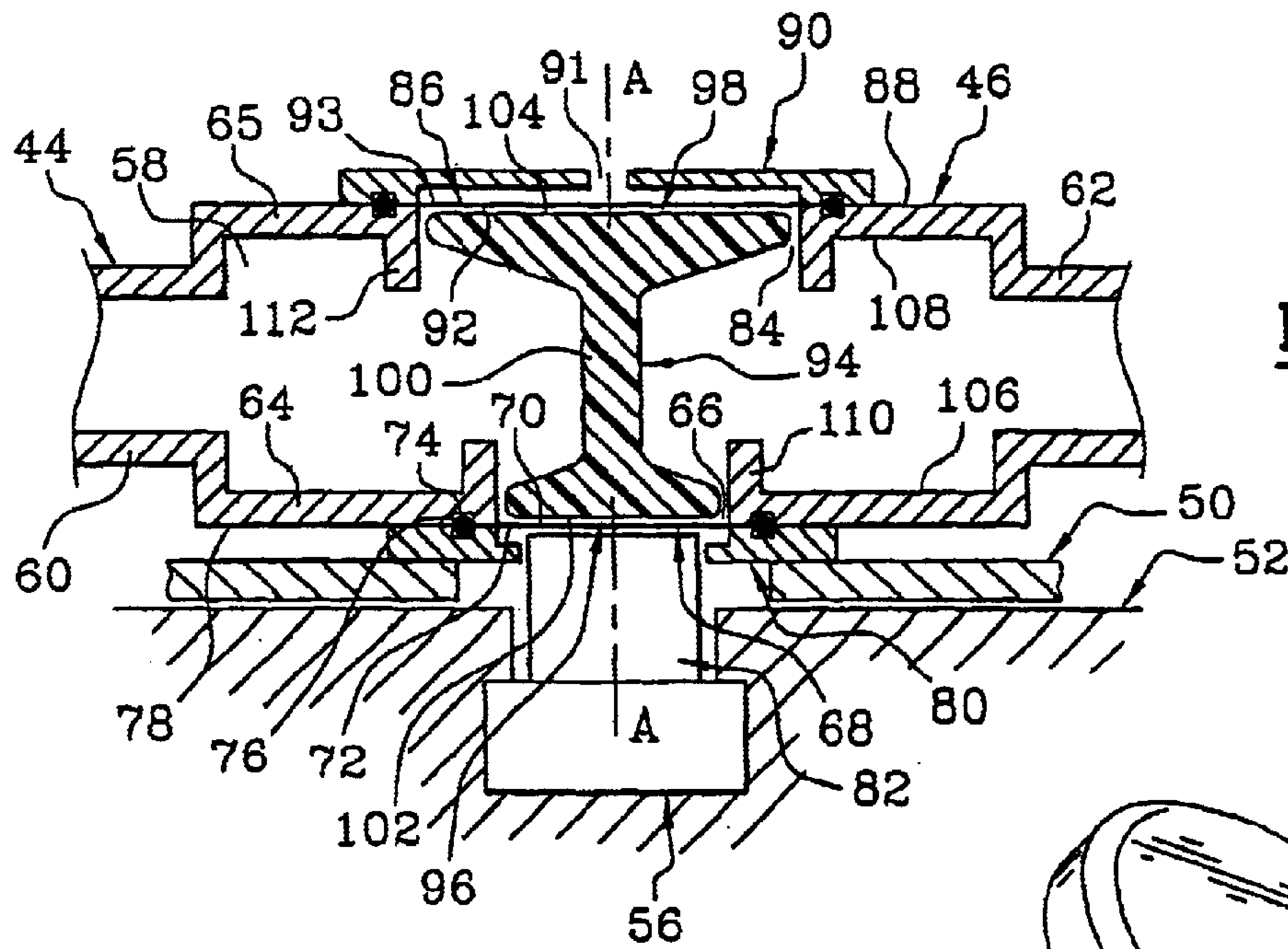


Fig. 6

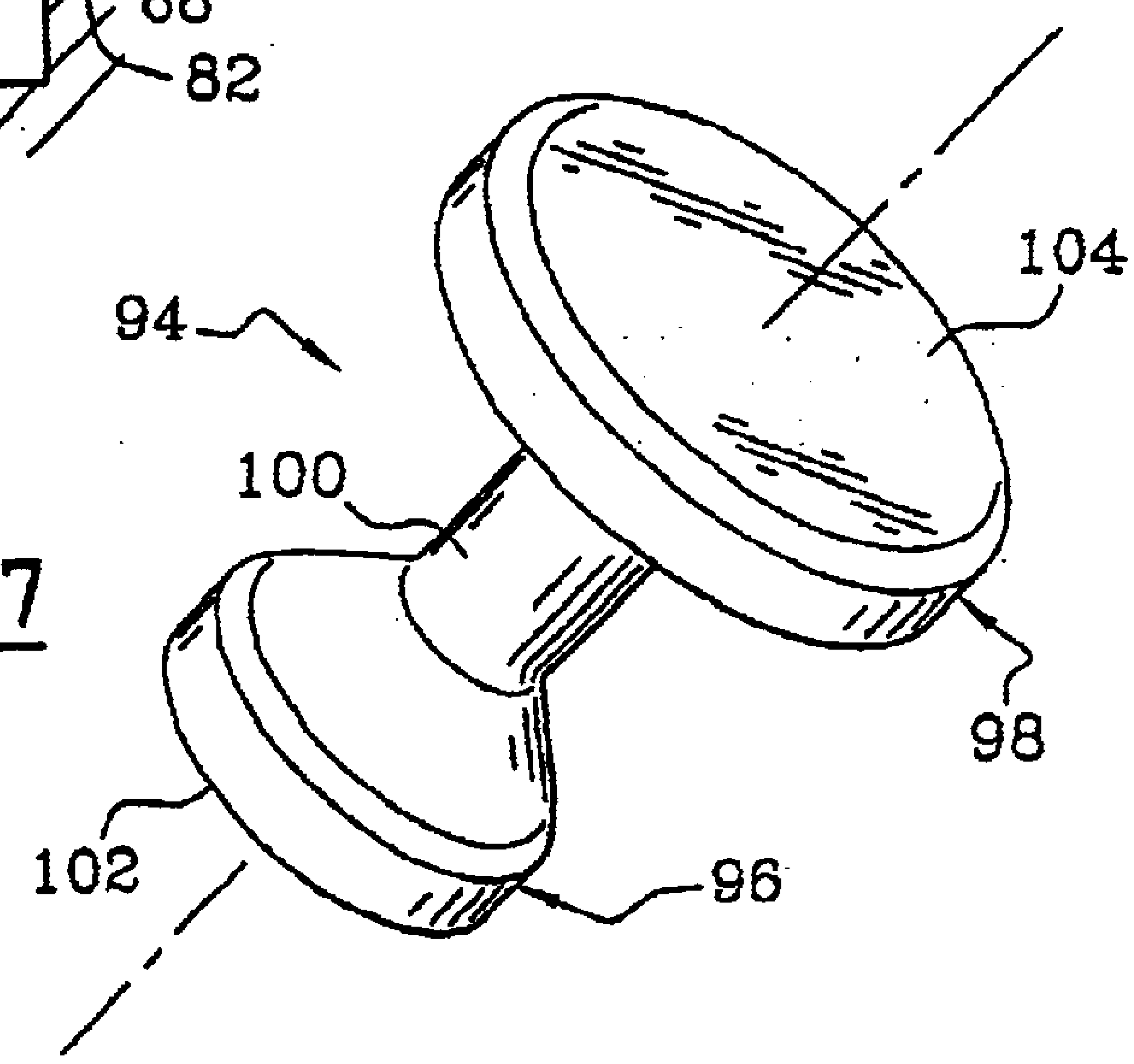


Fig. 7

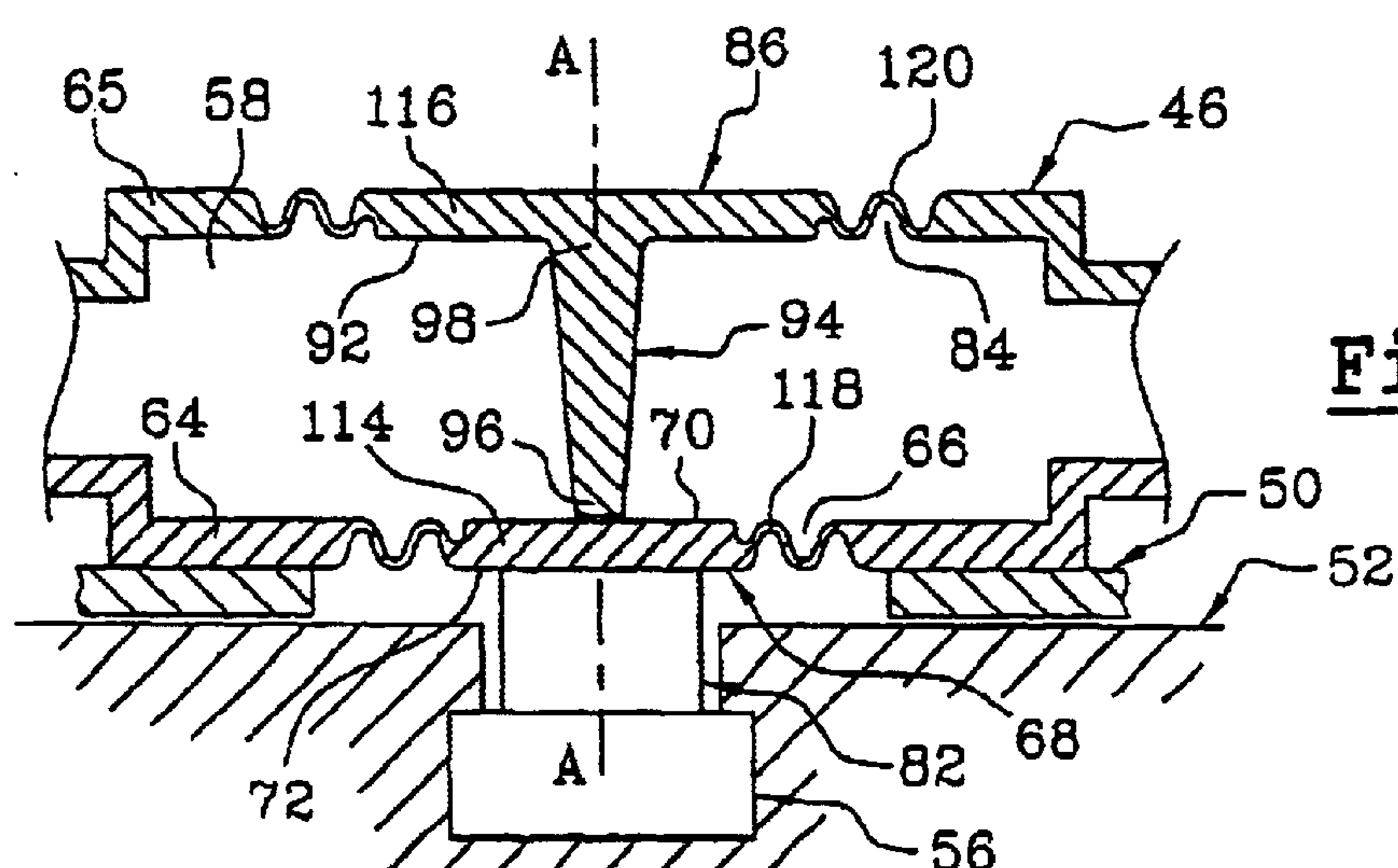


Fig. 8

DEVICE FOR MEASURING NEGATIVE PRESSURES IN AN EXTRACORPOREAL BLOOD CIRCUIT

FILED OF THE INVENTION

The present invention relates to a device for measuring blood pressure.

More particularly, the present invention relates to a device for measuring the pressure of blood which is used in an extracorporeal blood treatment device in which the blood is taken from a patient in order to be treated then reintroduced into the body of the patient (especially for the purpose of carrying out dialysis) by means of an extracorporeal blood circuit comprising pipes and including at least one section for measuring the pressure of blood circulating in a pipe.

BACKGROUND OF THE INVENTION

A known type of pressure measurement section forms a compartment which is delimited especially by a main wall and by a secondary wall facing it, the two walls being substantially rigid and parallel; the main wall comprises a hole which is sealed by a main closure element, the internal face of which is in contact with the blood and the external face of which is in contact with the ambient air, it being possible to elastically deform or displace the entire main closure element along a deformation or displacement axis which is substantially orthogonal to its general plane, under the effect of the blood pressure; a portion of the external face of the main closure element, in its rest state, is in direct or indirect contact with a load sensor which is able to measure the force applied axially to the internal face of the main closure element by the pressure of the blood, in order to calculate therefrom the value of this pressure.

Generally, this type of extracorporeal blood treatment device comprises a circuit part which is formed from a casing, or cassette, of the "disposable" type, integrating pipes which are connected to the extracorporeal blood circuit.

The pressure measurement section may be an attached module which is mounted in a housing associated with the casing.

The casing is mounted on a support apparatus which comprises, for example, sensors, display means, pumping means, a control interface, an electronic control unit, etc.

In this type of extracorporeal blood treatment device, the blood pressure must be measured without contact between the measuring member and the blood.

Several systems for carrying out this pressure measurement are known.

In a first pressure measurement system, which is shown in FIG. **1**, a pressure measurement section **10** in a pipe **12** comprises a measurement chamber **14** in which a membrane **16**, or diaphragm, separates the blood flowing in the pipe **12** from the air contained in a compartment **18**.

The membrane **16** can be deformed along a deformation axis A—A orthogonal to its general plane, such that it is axially displaced according to the blood pressure in the pipe **12**.

The extreme deformation positions of the membrane **16** are shown in dotted lines.

The air compartment **18** is sealed shut when the pressure measurement section **10** is mounted on a support apparatus **20**.

The support apparatus **20** comprises a sensor **22** which directly measures the pressure in the air compartment **18**.

When the blood pressure changes, the membrane **16** is axially displaced to an equilibrium position in which the pressure is equal on each side of the membrane **16**.

The pressure measured by the sensor **22** in the air compartment **18** is therefore equal to the blood pressure in the pipe **12**.

By virtue of a suitable geometry, in particular by virtue of a suitable volume of the compartment **18** and a suitable surface for the membrane **16**, this first pressure measurement system makes it possible to measure, on the one hand, so-called "positive" blood pressures, that is blood pressures which are greater than a reference pressure, in this case atmospheric pressure, and, on the other hand, so-called "negative" blood pressures, that is blood pressures which are less than the reference pressure.

This measurement system operates correctly provided there are no leaks in the air compartment **18**, otherwise the membrane **16** is then displaced to its end stop and it no longer carries out the function of transmitting pressure.

The sealing of the air compartment **18** during mounting of the pressure measurement section **10** on the support apparatus **20** is a weak point of the measurement system.

In particular, the seal may be impaired while the measurement system is in use.

In a second pressure measurement system, which is shown in FIG. **2**, the pressure measurement section **10** forms a compartment **24** containing the blood and a wall **26** of which includes a hole **28** which is sealed by a flexible membrane **30**.

When the pressure measurement section **10** is mounted on the support apparatus **20**, the external face of the central part of the flexible membrane **30** is in contact with a load transmitter **32** which is inserted between the membrane **30** and a load sensor **34**.

The load sensor **34** makes it possible to measure the forces applied to the internal face of the membrane **30** due to the effect of the blood pressure in the compartment **24**, when the blood pressure is greater than the ambient air pressure.

The blood pressure is calculated from the equation:

$$P = \frac{F - F_0}{S_a} \quad (1)$$

In this equation, F is the force measured by the load sensor **34**, F_0 is the force measured in the rest state, that is in the absence of a pressure gradient between the two sides (external and internal faces) of the membrane **30**, and S_a is the area of the active surface of the membrane **30**.

The area of the active surface S_a of the membrane **30** has a value between the total area of the internal face of the membrane **30** in contact with the blood and the area of contact between the membrane **30** and the load transmitter **32**.

For very flexible membranes **30**, the active surface S_a is substantially equivalent to the area of contact between the membrane **30** and the load transmitter **32**.

This measurement system makes it possible to measure a positive pressure but it does not allow a negative pressure to be measured.

This is because, for negative pressures, the membrane **30** tends to come away from the load transmitter **32**. The load sensor **34** can therefore no longer measure the forces which are applied to the membrane **30**.

This system has therefore been adapted to measure negative pressures.

In order that the load sensor **34** can continue to measure the forces which are applied to the membrane **30**, when the blood pressure is negative, the membrane **30** is secured in axial displacement to the load transmitter **32**.

Thus, according to an improved embodiment of the second pressure measurement system, which is shown in FIG. **3**, the membrane includes a metal disc **36** on its external face and the load transmitter **32** includes a magnet **38** at its axial end facing the membrane **30**.

The magnetic attraction exerted by the magnet **38** on the metal disc **36** makes it possible to secure the membrane **30** in axial displacement to the load transmitter **32**.

When the pressure is positive, the membrane **30** exerts an axial force which pushes against the load transmitter **32**.

When the pressure is negative, the membrane **30** exerts an axial force which pulls on the load transmitter **32**.

This device for securing the membrane **30** to the load transmitter **32** is expensive since it requires a special membrane **30** fitted with a metal disc **36** and a special load transmitter **32** fitted with a magnet **38**.

The metal disc **36** must have a large area in order to allow effective magnetic coupling.

Furthermore, the membrane **30** experiences a significant jolt when the metal disc **36** "sticks" to the magnet **38** of the load transmitter **32**, which could impair its mechanical characteristics.

The invention aims to remedy these drawbacks.

SUMMARY OF THE INVENTION

For this purpose, the invention proposes a device for measuring the pressure of blood in a pipe of an extracorporeal blood circuit, comprising a pressure measurement section having a compartment which is delimited especially by a main wall and by a secondary wall facing it, the two walls being substantially rigid and parallel, the main wall having a hole which is sealed by a main closure element, the internal face of which is in contact with the blood and the external face of which is in contact with the ambient air, it being possible to elastically deform or displace the entire main closure element along a deformation or displacement axis, which is substantially orthogonal to its general plane, under the effect of the blood pressure, the main closure element being designed to engage with a load sensor so that a portion of the external face of the main closure element, in its rest state, is in direct or indirect contact with the load sensor which can measure the force applied axially to the internal face of the main closure element by the blood pressure, in order to calculate therefrom the value of this pressure, characterized in that the pressure measurement section comprises:

in its secondary wall, facing the hole of the main wall, a secondary hole which is sealed by a secondary closure element similar to the main closure element, the deformation or displacement axis of which is substantially coincident with that of the main closure element, the area of the internal face of the secondary closure element being greater than the area of the internal face of the main closure element, such that when the pressure of the blood is less than the pressure of the ambient air, the axial displacement of the secondary closure element towards the main closure element is greater than the axial displacement of the main closure element towards the secondary closure element;

and comprising, in the compartment, a transmission spacer which, when the pressure of the blood and the pressure of the ambient air are substantially equal, occupies a rest position in which it is in contact by a first axial end with the internal face of the main closure element and, by a second axial end, with the internal face of the secondary closure element;

such that when the blood pressure is less than the ambient air pressure, the spacer transmits the axial displacement, in the direction of the load sensor, from the secondary closure element to the main closure element, so that the load sensor can measure the resultant axial force in order to calculate therefrom the value of the blood pressure.

According to other characteristics of the invention:

the pressure measurement section comprises axial displacement guiding means for the transmission spacer;

the spacer has an axial rod provided, at least at one of its axial ends, with an axial support plate, the external face of which is adjacent and substantially parallel to the internal face of the associated closure element, when the spacer occupies its rest position;

the rod comprises a support plate at each one of its axial ends;

the area of the external face of each support plate is substantially equal to the area of the internal face of the associated closure element;

each of the closure elements and each of the support plates has substantially the shape of a disc;

the internal face of the main wall and the internal face of the secondary wall each comprise a rim, around the associated closure element, which extends axially towards the inside and which delimits a section of guide tube of a diameter substantially equal to the diameter of the associated support plate, for the purpose of axially guiding the transmission spacer;

the transmission spacer is attached to one of the closure elements;

at least one closure element is made in a single piece with the associated rigid wall, and the transmission spacer is made in a single piece with one closure element which is made in a single piece with the associated rigid wall;

the transmission spacer is made by moulding with a closure element which is itself made by moulding with the associated rigid wall;

the transmission spacer is secured in axial displacement to the secondary closure element;

the area of the secondary closure element is substantially twice the area of the main closure element;

the pressure measurement section comprises a sensor which identifies the direction of the axial displacement of the secondary closure element, so as to determine whether the axial force measured by the load sensor corresponds to a measurement of blood pressure which is above or below the pressure of the ambient air.

BRIEF DESCRIPTION OF THE DRAWINGS

Other characteristics and advantages of the invention will appear on reading the following detailed description, for the understanding of which reference may be made to the appended drawings in which:

FIG. **1** is a cross-sectional schematic view showing a first type of pressure measurement system according to the prior art;

FIG. **2** is a view, similar to that of FIG. **1**, which shows a second type of pressure measurement system according to the prior art;

FIG. **3** is a view, similar to that of FIG. **1**, which shows an improvement to the pressure measurement system of FIG. **2** according to the prior art;

FIG. **4** is a perspective view which shows schematically an extracorporeal blood treatment device made according to the teachings of the invention;

FIG. **5** is a top view which shows schematically the cassette of the device of FIG. **4**;

FIG. **6** is a view, similar to that of FIG. **1**, which shows a pressure measurement section of the device of FIG. **4**, according to the teachings of the invention;

FIG. **7** is a schematic perspective view which shows the transmission spacer of the pressure measurement section of FIG. **6**;

FIG. **8** is a view, similar to that of FIG. **1**, which shows a variant of the pressure measurement section of FIG. **6** comprising closure elements moulded in their associated rigid walls.

In the following description, identical or similar elements will be denoted by identical references.

FIG. **4** shows an extracorporeal blood treatment device **40** for the purpose of carrying out dialysis.

DETAILED DESCRIPTION OF THE INVENTION

This device **40** is designed to take blood from a patient, to treat it for the purpose of carrying out dialysis, then to reintroduce it into the body of the patient.

This device **40** comprises an extracorporeal blood circuit **42** (here shown only in part) having pipes **44** and comprising at least one section **46** for measuring the pressure of blood flowing in a pipe **44**.

In this case, part of the extracorporeal blood circuit **42** is formed by a substantially parallelepipedal casing **48**, also called cassette, which contains in its thickness pipes **44** for the blood flow, which are connected to other pipes **44** of the extracorporeal blood circuit **42**.

In this case, the cassette **48** comprises two similar pressure measurement sections **46** which are contained therein.

The cassette **48** is designed to be mounted on a support plate **50** of a dialysis apparatus **52** which comprises, in particular, pumping means **54** to make the blood flow in the circuit **42** and means for controlling certain parameters of the circuit **42**, in particular load sensors **56** which engage with the sections **46** in order to control the pressure in the pipes **44** of the circuit **42**.

The cassette **48** is made, for example by moulding, of polycarbonate or polypropylene or of another suitable material.

In the rest of the description, only a single section **46** will be described.

The pressure measurement section **46**, which is shown schematically in FIG. **6**, in this case forms a substantially parallelepipedal compartment **58** which is inserted between two branches **60**, **62** of a pipe **44**, and which is for example moulded with the cassette **48**.

According to an alternative embodiment (not shown) of the pressure measurement section **46**, the latter may be a module attached to the cassette **48**.

The compartment **58** is delimited especially by a main wall **64** and a secondary wall **65** which are substantially rigid and parallel.

The main wall **64** includes a hole **66** which is sealed by a main closure element **68**, the internal face **70** of which is in contact with the blood and the external face **72** of which is in contact with the ambient air.

In the rest of the description, an axial orientation will be defined as following an axis A—A which is substantially orthogonal to the general plane of the main wall **64** and which passes through the centre of the hole **66**.

When the cassette **48** is mounted on its support plate **50**, the main wall **64** of the pressure measurement section **46** is designed to be placed facing the support plate **50**, so that the main closure element **68** is facing a load sensor **56**.

FIG. **5** shows the cassette **48** seen from the side of the main wall **64**.

In this case, the main closure element **68** is a flexible membrane which is substantially disc-shaped.

In FIG. **6**, the main membrane **68** has a peripheral torus-shaped beading **74** for its assembly in a complementary annular groove **76** which is made in the external face **78** of the main wall **64**, in the vicinity of the hole **66**.

A retaining ring **80** is fixed, for example by adhesive bonding, to the external face **78** of the main wall **64**, over the torus-shaped beading **74**, so as to axially retain the main membrane **68**.

It is possible to deform the entire main membrane **68** along a deformation axis A—A which is substantially orthogonal to its general plane, under the effect of the blood pressure.

When the main membrane **68** is in its rest state, that is, when it is not deformed, since the blood pressure is substantially equal to the ambient air pressure, the central part of its external face **72** is in contact with a load transmitter **82**, itself attached to a load sensor **56**.

The load sensor **56** measures the force applied axially to the internal face **70** of the main membrane **68** by the blood pressure, in order to calculate therefrom the value of the said pressure.

Advantageously, the load sensor **56** is of the strain gauge type.

Note that when the system is in the rest state, the main membrane **68** is lightly tensioned, that is elastically deformed, by the force transmitter **82**, by an initial axial pressing force F_0, so as to guarantee contact between the main membrane **68** and the force transmitter **82**.

In accordance with the teachings of the invention, the compartment **58** comprises, in its secondary wall **65**, facing the hole **66** of the main wall **64**, a secondary hole **84** which is sealed by a secondary closure element **86** similar to the main closure element **68**, in this case by a secondary flexible membrane.

The secondary membrane **86** is attached to the external face **88** of the secondary wall **65** in a manner similar to the main membrane **68**, by a secondary retaining ring **90**.

Advantageously, the secondary ring **90** is almost closed, which makes it possible to protect the secondary membrane **86**, and it therefore includes a central orifice **91** of small diameter.

The central orifice **91** makes it possible to put the external face **93** of the secondary membrane **86** in contact with the ambient air.

The deformation axis A—A of the secondary membrane **86** is substantially coincident with that of the main membrane **68**.

The area of the internal face **92** of the secondary membrane **86** is greater than the area of the internal face **70** of the main membrane **68** such that, when the blood pressure is less than the ambient air pressure, the axial deformation of the secondary membrane **86** in the direction of the main membrane **68** is greater than the axial deformation of the main membrane **68** in the direction of the secondary membrane **86**.

The compartment **58** also comprises a transmission spacer **94** which is inserted axially between the two membranes **68, 86**.

When the blood pressure and the ambient air pressure are substantially equal, the spacer **94** occupies a rest position in which it is in contact, by a main axial end **96**, with the internal face **70** of the main membrane **68** and, by a secondary axial end **98**, with the internal face **92** of the secondary membrane **86**.

In this case, the spacer **94** has the overall shape of a "bobbin", as shown in FIG. **7**.

It comprises an axial rod **100** which is fitted, at each of its axial ends, with an axial support plate **96, 98**, or end plate, the external face **102, 104** of which is adjacent and substantially parallel to the internal face **70, 92** of the associated membrane **68, 86**, when the spacer **94** is in its rest position.

Each support plate **96, 98** in this case has the overall shape of a disc, the diameter of which is substantially equal to the diameter of the internal face **70, 92** of the associated membrane **68, 86**.

Advantageously, the internal face **106** of the main wall **64** and the internal face **108** of the secondary wall **65** each have a rim **110, 112**, around the associated hole **66, 84**, which extends axially towards the inside and which delimits a guide tube section with a diameter substantially equal to the diameter of the associated support plate **96, 98** of the spacer **94**, for the purpose of axially guiding the transmission spacer **94**.

The axial guiding of the spacer **94** makes it possible to prevent it being offset transversely, or about a rotation axis which is substantially transverse with respect to the deformation axis A—A of the membranes **68, 86**.

Note that the spacer **94** is made, preferably by moulding of a light material, for example of polycarbonate or polypropylene.

When the blood pressure in the compartment **58** is greater than the ambient air pressure, that is when the pressure is called "positive", the spacer **94** does not affect the operation of the membranes **68, 86** since the two membranes **68, 86** are deformed axially towards the outside, moving away from the spacer **94**, the main membrane **68** applying a main axial pressing force F_p against the force transmitter **82**.

The absolute value of the main force F_p can thus be expressed as follows:

$$F_p = F_0 + p \cdot S_p \tag{2}$$

In this equation (2), F_0 is the initial axial pressing force measured by the load sensor in the rest state of the pressure measurement system, p is the difference between the blood pressure and the ambient air pressure which are applied to the membranes **68, 86**, and S_p is the area of the active surface of the main membrane **68**.

When the blood pressure in the compartment **58** is less than the ambient air pressure, that is when the pressure is called "negative", the two membranes **68, 86** tend to be deformed axially towards the inside of the compartment **58**.

The main membrane **68** then exerts a main axial pressing force F_p on the external face **102** of the main plate **96** directed towards the secondary membrane **86**, and the secondary membrane **86** then exerts a secondary axial pressing force F_S on the external face **104** of the secondary plate **98** directed towards the main membrane **68**.

The two forces F_p, F_S are therefore in opposite directions.

The absolute value of the main force F_p can be expressed as follows:

$$F_p = p \cdot S_p \tag{3}$$

In this equation (3), p is the difference between the blood pressure and the ambient air pressure which are applied to the membranes **68, 86**, and S_p is the area of the active surface of the main membrane **68**.

The absolute value of the secondary force F_s can be expressed in a manner similar to equation (3), as follows:

$$F_s = p \cdot S_s \tag{4}$$

In this equation (4), S_s is the area of the active surface of the secondary membrane **86**.

By design, the area S_s of the active surface of the secondary membrane **86** is greater than the area S_p of the active surface of the main membrane **68**.

The secondary force F_s is therefore greater than the main force F_p.

Advantageously, a secondary active surface S_s is chosen, the area of which is equal to twice that of the main active surface S_p.

The absolute value of the secondary force F_s can then be expressed as follows:

$$F_s = 2p \cdot S_p \tag{5}$$

The absolute value of the resultant axial force F_r, which is applied to the load transmitter **82** and which is directed from the main membrane **68** to the load sensor **56**, is then expressed as follows:

$$F_r = F_0 + F_s - F_p = F_0 + p \cdot S_p \tag{6}$$

In this equation, F_0 is the initial axial pressing force, or pretensioning force, which is measured by the load sensor in the rest state of the pressure measurement system.

Consequently, for the same pressure difference p, the resultant force F_r of equation (6) and the main force F_p of equation (2) are equal.

For the same pressure difference p, whatever the direction of the pressure variation, the load sensor **56** will measure an identical value of force F_r and it will therefore calculate therefrom a same value of blood pressure.

Note that the spacer **94** makes it possible to transmit the resultant force F_r to the main membrane **68** and therefore to the load transmitter **82**.

Note also that the load sensor **56** is not capable of determining whether the axial pressing force that it measures corresponds to a positive or negative blood pressure.

According to an alternative embodiment (not shown) of the invention, an additional sensor is placed in the vicinity of the central part of the external wall **93** of the secondary membrane **86**, so as to detect, for example, a possible axial deformation of the secondary membrane **86** towards the outside.

If the additional sensor detects such an axial deformation, it can then be deduced that the force measured by the load sensor **56** corresponds to a positive pressure, otherwise it can be deduced that the force measured by the load sensor **56** corresponds to a negative pressure.

It is found that the greater the difference between the area of the internal face **70** of the main membrane **68** and the area of the internal face **92** of the secondary membrane **86**, the more the sensitivity and efficiency of the negative pressure measurement increases.

However, the area of the internal face **70** of the main membrane **68** should not be too small otherwise the mechanical ability for axial deformation of the main membrane **68** is decreased and the sensitivity of the main membrane **86** to the resultant force F_r transmitted by the spacer **94**, is decreased.

According to an alternative embodiment (not shown) of the invention, one of the support plates **96**, **98** of the transmission spacer **94** is attached by known means to the associated membrane **68**, **86**, for example by adhesive bonding.

Note that the transmission spacer **94** should not be attached to the two membranes **68**, **86**, otherwise, in the case of positive pressure, the secondary membrane **86** would cause the main membrane **68** to be axially displaced towards the outside, on the side opposite the load transmitter **82**, which would distort the measurements carried out by the load sensor **56**.

FIG. **8** shows an alternative embodiment of the invention in which the closure elements **68**, **86** of the holes **66**, **84** of the main wall **64** and the secondary wall **65**, respectively, are each made in a single piece with the associated wall **64**, **65**.

In this case, each closure element **68**, **86** comprises a disc-shaped substantially rigid central pellet **114**, **116**, which is delimited by a thinned peripheral annular region **118**, **120** with an axial thickness less than the axial thickness of the associated rigid wall **64**, **65**, so as to form an elastically deformable region.

Thus, under the effect of the blood pressure in the compartment **58**, and by virtue of the elastic deformation of its thinned region **118**, **120**, it is possible for each central pellet **114**, **116** to be displaced overall along a displacement axis which is substantially orthogonal to the general plane of the pellet **114**, **116** and which corresponds to the deformation axis A—A of the membranes **68**, **86** of the embodiment shown in FIG. **6**.

In its rest state, the external face **72** of the central pellet **114** of the main closure element **68**, or main pellet **114**, is in contact with the load transmitter **82**.

Advantageously, the transmission spacer **94** is made in a single piece, in this case by moulding, with the central pellet **116** of the secondary closure element **86**, or secondary pellet **116**.

In the embodiment which is shown here, the transmission spacer **94** has the shape of a frustoconical finger, the base **98** of which is moulded on the internal face **92** of the secondary pellet **116** and the free axial end **96** of which bears axially against the internal face **70** of the main pellet **114**, when the system is in its rest state.

Of course, it is possible to combine the different characteristics which have been described above, without departing from the field of the present invention.

What is claimed is:

1. Device for measuring the pressure of blood in a pipe **(44)** of an extracorporeal blood circuit **(42)**, comprising a pressure measurement section **(46)** having a compartment **(58)** which is delimited especially by a main wall **(64)** and by a secondary wall **(65)** facing the main wall **(64)**, the two walls **(64, 65)** being substantially rigid and parallel, the main wall **(64)** having a hole **(66)** which is sealed by a main closure element **(68)** having an internal face **(70)** which is in contact with the blood and an external face **(72)** which is in contact with the ambient air, the entire main closure element **(68)** being elastically deformable or displaceable along a deformation or displacement axis (A—A), which is substantially orthogonal to its general plane, under the effect of the blood pressure, the main closure element **(68)** being designed to engage with a load sensor **(56)** so that a portion of the external face **(72)** of the main closure element **(68)**, in its rest state, is in direct or indirect contact with the load sensor **(56)** which can measure the force applied axially to the internal face **(70)** of the main closure element **(68)** by the blood pressure, in order to calculate therefrom the value of this pressure, characterized in that the pressure measurement section **(46)** comprises:

in its secondary wall **(65)**, facing the hole **(66)** of the main wall **(64)**, a secondary hole **(84)** which is sealed by a secondary closure element **(86)** having a deformation or displacement axis (A—A) which is substantially coincident with that of the main closure element **(68)**, the area of the internal face **(92)** of the secondary closure element **(86)** being greater than the area of the internal face **(70)** of the main closure element **(68)**, such that when the pressure of the blood is less than the pressure of the ambient air, the axial displacement of the secondary closure element **(86)** towards the main closure element **(68)** is greater than the axial displacement of the main closure element **(68)** towards the secondary closure element **(86)**;

and comprising, in the compartment **(58)**, a transmission spacer **(94)** which, when the pressure of the blood and the pressure of the ambient air are substantially equal, occupies a rest position in which the transmission spacer **(94)** is in contact by a first axial end **(96)** with the internal face **(70)** of the main closure element **(68)** and, by a second axial end **(98)**, with the internal face **(92)** of the secondary closure element **(86)**;

such that when the blood pressure is less than the ambient air pressure, the spacer **(94)** transmits the axial displacement, in the direction of the load sensor **(56)**, from the secondary closure element **(86)** to the main closure element **(68)**, so that the load sensor **(56)** can measure the resultant axial force in order to calculate therefrom the value of the blood pressure.

2. Device according to claim **1**, characterized in that the pressure measurement section **(46)** comprises axial displacement guiding means **(110, 112)** for the transmission spacer **(94)**.

3. Device according to claim **1**, characterized in that the spacer **(94)** has an axial rod **(100)** provided, at least at one of its axial ends, with an axial support plate **(96, 98)**, the external face **(102, 104)** of which is adjacent and substantially parallel to the internal face **(70, 92)** of the associated closure element **(68, 86)**, when the spacer **(94)** occupies its rest position.

4. Device according to claim **3**, characterized in that the rod **(100)** comprises a support plate **(96, 98)** at each one of its axial ends.

5. Device according to claim **3**, characterized in that the area of the external face **(102, 104)** of each support plate **(96, 98)** is substantially equal to the area of the internal face **(70, 92)** of the associated closure element **(68, 86)**.

6. Device according to claim **3**, characterized in that each of the closure elements **(68, 86)** and each of the support plates **(96, 98)** has substantially the shape of a disc.

7. Device according to claim **3**, characterized in that the internal face **(106)** of the main wall **(64)** and the internal face **(108)** of the secondary wall **(65)** each comprise a rim **(110, 112)**, around the associated closure element **(68, 86)**, which extends axially towards the inside and which delimits a section of guide tube of a diameter substantially equal to the diameter of the associated support plate (**96**, **98**), for the purpose of axially guiding the transmission spacer (**94**).

8. Device according to claim **1**, characterized in that the transmission spacer (**94**) is attached to one of the closure elements (**68**, **86**).

9. Device according to claim **1**, characterized in that at least one closure element (**68**, **86**) is made in a single piece with the associated rigid wall (**64**, **65**), and in that the transmission spacer (**94**) is made in a single piece with one of the closure elements (**68**, **86**) which is made in a single piece with the associated rigid wall (**64**, **65**).

10. Device according to claim **9**, characterized in that the transmission spacer (**94**) is made by moulding with a closure element (**86**) which is itself made by moulding with the associated rigid wall (**65**).

11. Device according to claim **8**, characterized in that the transmission spacer (**94**) is secured in axial displacement to the secondary closure element (**86**).

12. Device according to claim **1**, characterized in that the area of the secondary closure element (**86**) is substantially twice the area of the main closure element (**68**).

13. Device according to claim **1**, characterized in that the pressure measurement section (**46**) comprises a sensor which identifies the direction of the axial displacement of the secondary closure element (**86**), so as to determine whether the axial force measured by the load sensor (**56**) corresponds to a measurement of blood pressure which is above or below the pressure of the ambient air.

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